The corpus callosum (CC), the largest interhemispheric commissure, connects the cortical zones of the left and right hemispheres. The anterior regions of the CC contain axons from the frontal, premotor, and motor cortices, and the posterior regions contain fibers from the somesthetic, parietal, occipital, and temporal lobes. The role of the CC has two major aspects. The first aspect suggests that CC is associated with functional cortical lateralization at the level of interhemispheric inhibition. The second aspect implies that CC contributes to brain symmetry because CC impairment leads to intrahemispheric isolation. These two models explain how CC can contribute to language lateralization. In this first tractography study, the research team from HSE University, Lomonosov State University, and the Institute of Linguistics, Russian Academy of Sciences, Moscow, Russia, investigated the association between the volumes and microstructural properties of the corpus callosum subregions and a degree of language lateralization.

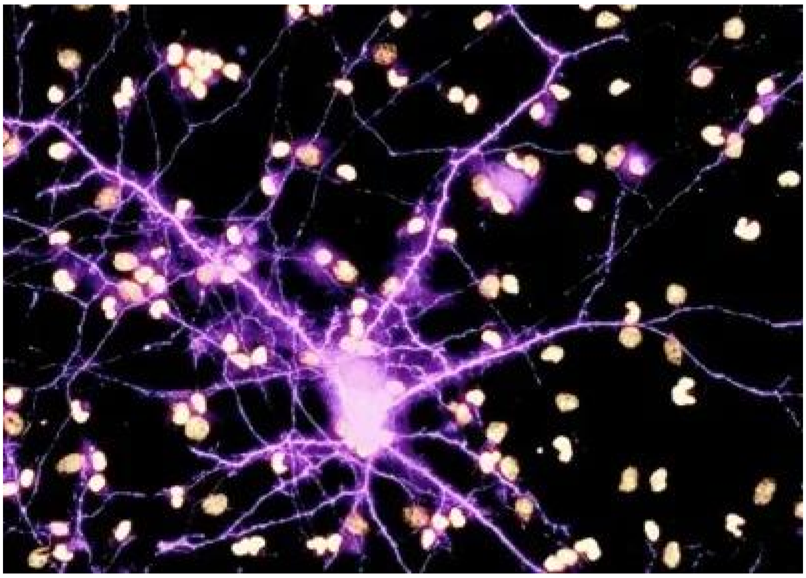
Corpus callosum

About the transcallosal cortico-cortical transmission

From the first observations made in the late 19th century, generations of scientists became interested in the origin and consequences of brain asymmetry, including hemispheric language dominance. Pioneering studies have pointed to the left hemisphere dominance in language and the right hemisphere dominance in the affective, prosodic, and intonational aspects of spoken language and emotional word processing. Later studies have also documented a dominance of the left hemisphere for language in most humans. However, about 10–15% of individuals show atypical dominance for language in the right hemisphere or no clear hemispheric dominance. This is more frequently represented in the left-handed and ambidexters than in the right-handed people.

The authors stressed the efforts over the past decades to find anatomical correlates for language lateralization in gray and white matter structures. Early tractography studies of language lateralization used diffusion tensor imaging (DTI) to investigate only the microstructural properties, but CC subregion volumes were not explored.

Transcallosal cortico-cortical transmission is mainly excitatory, but the main and longer-lasting effect in the contralateral hemisphere is inhibitory, probably because most excitatory callosal fibers terminate on pyramidal neurons, which then activate inhibitory interneurons. These activated inhibitory cells may then induce a widespread inhibition in homotopic regions of contralateral neurons. Since most CC fibers rely on excitatory glutamate neurotransmitters, the excitatory model suggests the functional activation of both hemispheres through the CC. According to the inhibitory model, the dominant hemisphere suppresses the subdominant hemisphere during language tasks through the inhibitory interneurons.



About the study

The authors used two tractography techniques, diffusion tensor imaging (DTI) and constrained spherical deconvolution (CSD), to investigate the association between the structural properties of each callosal subregion and the degree of language lateralization in the corresponding cortical areas. The CSD is an advanced tractography technique for modeling the CC crossing fibers.

The study included 50 neurologically healthy individuals; 20 were right-handed, 20 were left-handed, and 10 participants were ambidextrous. They performed a block-designed language task with alternating sentence completion, which activates both anterior and posterior language-related areas.

The brain activity was recorded during the language task using functional magnetic resonance imaging (fMRI). Two tractography techniques, DTI and CSD, were used to measure the volumes and microstructural properties of the callosal subregions.

Results

The CSD findings revealed a significantly larger volume for each callosal subregion than DTI. This is consistent with some earlier work showing that CSD provides a more complete reconstruction of the crossing callosal fibers.

The microstructural properties of callosal fibers did not influence the degree of language lateralization, regardless of the tractography method.

Because of the microstructural property variability and potential functional specialization of the callosal subregions, the researchers analyzed the degree of language lateralization in each cortical area that corresponds to the specific callosal subregion. The DTI-based metrics did not show a significant association with language lateralization.

The CSD-based analysis revealed a significant impact only in the area that included language-related posterior brain regions. The volumes of corpus callosum subregions terminating in the posterior parietal, temporal, and occipital lobes predicted a stronger degree of language lateralization.

According to the authors, these findings support the specific inhibitory model implemented through the CC fibers and projected into the language-related posterior areas, with no relevant contribution from other callosal subregions. The relationship between the volume of CC fibers projecting into the parietal, temporal, and occipital lobes and the degree of language lateralization can be explained by the role that posterior callosal subregions play in language comprehension.

Conclusion

This first tractography study investigated the relationship between volumes and microstructural properties of callosal subregions and the degree of language lateralization in the corresponding cortical areas.

According to the CSD-based analysis, the volume of CC fibers terminating in the posterior parietal, temporal, and occipital lobes predicted a stronger degree of language lateralization. These findings show that the influence of callosal fibers on the degree of language lateralization is not equipotential but rather anatomically specific.

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https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0276721